discussed before and there is no need to repeat the argument here. If the quality of the data which constitute the program's input is low the gain may be fairly slight, but diagnoses derived by a computer from unreliable data will still be at least as useful as those derived from the same data by other means. But the development and progressive refinement of computer programs for generating diagnoses have other less immediate but equally important consequences. By creating, as they do, a range of experimental models simulating the process by which clinicians arrive at diagnoses, they focus attention on the largely unexplored mechanisms of diagnostic pattern recognition and decision making. By producing, as they also do, a variety of alternative diagnostic criteria, each of them explicit and available for public scrutiny, they serve to focus attention on the neglected issue of the validity of our diagnoses. Consider, for example, a situation in which three different programs are in use simultaneously, all embodying different concepts of schizophrenia. In such a situation psychiatrists would be forced to consider which of the three concepts was the most useful, and in so doing to decide what their criterion of usefulness or validity was to be. Alternatively, a situation might well arise in which one particular program came into general use, perhaps in combination with a particular interviewing schedule or rating scale. Such a development would have profound implications, much greater than those accompanying the popularization of other instruments like the MMPI or the Rorschach Test. For whoever exports his program also exports his diagnostic criteria. We could well find that the diagnostic criteria currently used in one particular country, or even in a particular university department, might come into general use in the wake of the widespread adoption of a popular computer program embodying those criteria. For these and other reasons the application of computer technology to psychiatric diagnosis may prove to be a development of much greater moment than is yet apparent.

DECISION TREE PROGRAMS

Three quite different kinds of computer program have been used for generating diagnoses; those based on a logical decision tree, those based on probability theory and those based on multiple discriminant functions. The decision tree method is the easiest to understand for those with little knowledge of statistics for the simple reason that it does not involve any. It consists purely of a series of questions each of which has to be answered yes or no. Each successive answer eliminates one or more diagnoses or groups of diagnoses and also determines the next question asked, until every diagnosis but one has been eliminated. For example, the first question, based on a group of items concerned with cognitive functioning, might be used to determine whether the illness was organic or not. If the answer was 'no' the second question, based perhaps on a series of items about delusions and hallucinations, might determine whether the illness was psychotic or neurotic, and so on. In this way every possible combination of symptoms is reduced to one or other of the diagnoses recognized in the system. Individual questions may specify the presence of a single item, or that a score derived from several items should lie within a certain range, or be based on complex alternatives involving numerous items in different combinations. The formal structure of a decision tree is actually the same as that of a railway marshalling yard, with patients corresponding to individual trucks, the yes/no questions to sets of points and the trains at the bottom of the yard to diagnoses. When it starts its journey at the top of the yard each truck has the potential to join any of the trains, but each time it passes a set of points its choice becomes more restricted until eventually it is committed to one particular train.

Diagno

Spitzer's Diagno (Spitzer and Endicott, 1968) was the first program of this type to be developed. It is based on the thirty nine scale scores of a structured mental state interview known as the Psychiatric Status Schedule (see chapter 10) and allocates every patient to one of twenty seven diagnostic categories, including 'not ill' and 'non-specific illness with mild symptomatology'. It was soon followed by Diagno II (Spitzer and Endicott, 1969), a more complex program containing fifty seven decision points compared with Diagno's thirty six and incorporating a limited capacity to revise decisions made at an earlier stage in the sequence. This program utilizes historical data in addition to mental state information in the form of the Current and Past Psychopathology Scales (CAPPS – see Endicott and Spitzer, 1972) and generates a total of forty six different diagnoses, including personality disorders. In a study based on 100 sets of CAPPS ratings, and using K_w as an index of concordance. Spitzer and Endicott were able to show that the diagnostic agreement between Diagno II and clinicians was as good as that between one clinician and another, thus demonstrating the face validity as well as the reliability of the computer's diagnoses.

Catego

More recently Wing and his colleagues (Wing, Cooper and Sartorius, 1974) have developed a similar program, known as Catego, based on their structured Present State Examination. The design of this program is rather different from that of Diagno. Instead of single diagnoses or groups of diagnoses being eliminated one by one the original input, which consists of 350 PSE items, passes through a progressive series of condensations and all decisions about actual diagnoses are postponed until the final stage. The 350 items are first reduced to 140 'symptoms' and these in turn reduced to thirty five 'syndromes'. Next these syndromes are

condensed to six 'descriptive categories'. Up to this stage there is no restriction on the number of elements which any individual patient may exhibit but in the next stage, whether the patient has previously qualified for one descriptive category or all six, his symptomatology is reduced to a single 'descriptive class'. Essentially the same procedure is carried out independently with other data (if it is available) for all previous episodes of illness and the final 'provisional diagnostic class' is then derived from the separate descriptive class assignments of all episodes of illness, past or present. The Catego program prints out all the symptoms, syndromes and descriptive categories exhibited by each individual patient, together with a rough three point ranking (?, +, and ++) for each, in addition to the final 'provisional diagnostic class' or diagnosis. In this way much useful information is provided in a standardized form which enables unusual or borderline patients to be distinguished from those with typical symptom patterns.

The potential of this and similar programs was well illustrated in the International Pilot Study of Schizophrenia where it was used to derive standard 'diagnoses' from the PSE ratings of all 1200 patients from the nine countries involved (WHO, 1973a). In this way, several important similarities and differences in the range of patient types encountered in the nine countries were exposed, and also important similarities and differences in the diagnostic criteria of the local psychiatrists in each centre.

PROBABILISTIC METHODS

The second approach is a probabilistic or statistical one based on Bayes' theorem. The basic statement of this theorem is:

$$P(d_i/s_j) = \frac{P(d_i) \cdot P(s_j/d_i)}{\sum P(d_k) \cdot P(s_i/d_k)}$$

where

- $P(d_i/s_j)$ is the probability that a patient with the constellation of symptoms s_j has the disease d_i.
- $P(d_i)$ is the probability (or incidence) of the disease d_i in the population under consideration.
- $P(s_j/d_i)$ is the incidence of the symptoms s_j in the disease d_i.
- $P(d_k)$ is the incidence of each disease $1 \rightarrow k$ in the population.

and

- $P(s_j/d_k)$ is the incidence of the symptoms s_j in each of the diseases $1 \rightarrow k$.

Most of the early programs for deriving psychiatric diagnoses by computer were of this type (Birnbaum and Maxwell, 1961; Overall and Gorham, 1963; Overall and Hollister, 1964; Smith, 1966) but, in spite of the obvious relevance of probability theory to diagnosis, the Bayesian model has several disadvantages. It assumes that each of the symptoms $1 \rightarrow j$ is independent of the others and that the diseases $1 \rightarrow k$ are similarly independent of one another. In fact, neither of these assumptions is justified, though symptom independence can be artificially produced by replacing the actual ratings by principal components derived from them. The Bayesian model also requires a reasonable estimate of the incidence of the various symptoms $1 \rightarrow j$ in each of the diseases $1 \rightarrow k$ in the population under consideration, and a similar estimate of the relative frequency of these diseases in that population. In practice these data are rarely available and both Overall and Smith were forced to resort to the questionable procedure of using ratings of hypothetical typical cases to provide their estimates of the distributions of symptoms across diseases, and also to assume that each disease was equally probable.

DISCRIMINANT FUNCTIONS

The third group of techniques is based on the discriminant function procedures introduced by Fisher (1936) and Rao (1948). They are described in more detail in chapter 8, but in its simplest form discriminant analysis involves two populations, one whose members have been assigned a clinical diagnosis A and the other a diagnosis B, and all of whom have been rated for the presence or absence of N items relevant to the distinction between A and B. Starting with these data the anlaysis produces a linear variable (the discriminant function) consisting of a set of weights for the N items calculated so as to maximize the ratio of between-group to within-group variance. As a result, when a score is derived for each patient by adding together his weighted scores on the N items, the separation between those with diagnosis A and those with diagnosis B is maximal. Subsequently, this discriminant function can be used to allocate any patient who has been rated on the N items to the appropriate diagnosis, A or B. In practice several diagnoses are usually involved, not just two, which means using a multiple stepwise discriminant procedure, but the basic principle remains unchanged. Techniques of this sort have been used by Melrose, Stroebel and Glueck (1970) in Connecticut and Sletten, Ulett, Altman and Sunderland (1970) in Missouri. The latter at least were able to obtain a level of agreement between clinical and computer diagnoses comparable to that achieved by Spitzer with Diagno II and have since developed this computer service as a routine procedure in all the psychiatric hospitals in the Missouri State system (Sletten, Altman and Ulett, 1971). Using data from a mental state examination and standard demographic information the central computer provides for each patient within minutes, or at most a few hours, the probabilities of that patient belonging to each of eight broad diagnostic groupings [acute organic brain syndrome, paranoid schizophrenia, personality disorder, etc.]

The relative merits of the three approaches

It is debatable which of these three approaches corresponds most closely to the reasoning processes employed by clinicians. Claims have been made on behalf of all three, each of them with some justification. Really we know too little about the decision-making processes of clinicians to decide, and it may well be that they use different strategies in different situations. The hierarchical nature of most of our classifications, with each diagnosis excluding the presence of those that precede it and encompassing the symptoms of those that follow it, strongly suggests a sequence of decisions akin to that of a decision tree. On the other hand, clinicians are clearly influenced by considerations of relative probability comparable to those embodied in Bayes' Theorem. And when concerned with a particular differential diagnosis they may well allocate rough weights to the symptoms suggesting each of the two diagnoses and compare them in much the same way as a simple discriminant procedure does.

It is also arguable which of the three is the most useful. The decision tree method is the simplest, and also the easiest to construct, but each program is usable only with the particular rating scale or structured interview for which it was designed and individual diagnostic distinctions are necessarily based on rather crude criteria. The two statistical procedures share the important advantage that they provide not just a single diagnosis but an estimate, expressed as a probability by the Bayes method and as a distance by the discriminant function method, of how closely the patient resembles typical members of several different categories, thus allowing meaningful alternative diagnoses to be provided and distinguishing typical cases from those with unusual or borderline symptoms. However, both have disadvantages also. As we have already seen, Bayes' theorem makes the unjustified assumption that both symptoms and diagnoses are independent of one another, and also requires prior knowledge of the distributions of symptoms across diseases and, to achieve its full potential, prior knowledge of the relative incidence of the diseases under consideration as well. Discriminant function procedures start with several advantages. They involve fewer unfulfilled assumptions than the probabilistic approach, can handle numeric data without having to break them up into arbitrary nominal groups as the other two methods do, and have the ability to focus large amounts of data onto individual diagnostic discriminations to optimum effect. Their big disadvantage is that the linear functions they utilize have to be derived in the first place from ratings on large populations of patients, the size of the requisite population being governed by the product of the number of separate ratings or scores being used and the number of diagnostic categories to be distinguished. In practice, this means that unless a thousand or more sets of ratings are available one either has to confine oneself to distinguishing a small number of broad diagnostic groups, or make unjustified assumptions about variances and correlations across diagnostic categories and so fail to achieve anything like maximal discrimination. A second problem common to both the statistical methods is that, because their ground rules are derived in the first place from clinical ratings and diagnoses, the short-comings of these data are incorporated into the resulting program. If the initial data are unreliable and biased the program's rules will necessarily be in some respects inappropriate, and its discriminating power blunted as a result. This has two important consequences. The failure of a Bayesian or discriminant function program to generate appropriate diagnoses may be due to the short-comings of the clincial data from which it was derived rather than to the inherent short-comings of the statistical method. Conversely an improvement in the quality of the original developmental data may be expected to result in improved performance by the program.

Fleiss and his colleagues (Fleiss, Spitzer, Cohen and Endicott, 1972) have recently compared the efficacy of a logical decision tree program (Diagno II), a Bayesian program and a multiple discriminant function procedure at distinguishing twelve broad diagnostic categories in a series of 740 patients rated on the CAPPS. Over half these patients had to be used for developing the statistical rules of the Bayesian and discriminant function programs and the actual comparison was therefore restricted to the remaining 286 patients. Using K_w as an index of the degree of concordance between the original clinical diagnoses and the corresponding computer categories they found little difference between the three approaches; K_w lay between 0·43 and 0·48 for all three. However, the discriminant function program was less successful than the other two in reproducing the percentage distribution of the clinicians' diagnoses, mainly because it overdiagnosed paranoid schizophrenia at the expense of non-paranoid forms. When a second comparison was carried out on quite different data – CAPPS ratings obtained from a series of 435 women from an obstetric ward, and so with a much lower overall psychiatric morbidity than the previous material – Diagno came out best with an average K_w for concordance with the clinicians' diagnoses of 0·36, compared with 0·28 for the discriminant function program, and 0·20 for the Bayesian approach. The authors concluded from these results that 'at the present time, a logical decision tree method such as Diagno II is preferable for computer diagnosis to the Bayes and discriminant function methods'. This is a fair assessment of the current situation, though it is likely that discriminant function procedures will eventually prove superior once the practical problems of obtaining sufficiently large series of patients for developmental purposes have been overcome. The appropriate choice in any given situation will also be influenced by other considerations peculiar to that situation – how valuable it would be to have alternative diagnoses available as well as a single 'first choice' diagnosis, whether a wide range of separate diagnoses are needed or only an accurate assignment to a few major categories, and whether or not sufficient data are available to provide an adequate developmental sample for either of the statistical methods.

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